12

SOIL EROSION IN RELATION TO THE DEVELOPMENT OF LANDFORMS IN THE DUNDAS AREA OF WESTERN VICTORIA, AUSTRALIA

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[Read 11 December 1958]

Introduction

Soil erosion is usually considered to be caused by man. Yet there appears to be a close relationship between severe soil erosion and naturally unstable areas. Normal erosion is an imperceptible process; soil loss is balanced by soil formation. Yet even in virgin country erosion may become evident in exceptional circumstances, due to the acceleration of the normal processes of erosion after this balance has been upset. The amount of disturbance necessary to initiate accelerated erosion is dependent on the natural stability of the area. In this paper a naturally unstable area is considered to be one in which the balance between the processes of soil formation and the forces of erosion is precarious, and where a slight change of conditions will initiate marked accelerated erosion.

Soil erosion affects the productivity and economic unity of farms in many newly settled areas, and is most serious near the climatic margin of safe agriculture. Soil erosion is only a manifestation of the acceleration of the normal processes of erosion. The severity of this erosion depends on two fundamentals. These are, firstly, the resistance of a landscape to the forces of erosion and, secondly, the intensity of those forces. The former, to a large extent, is governed by the structure and strata of the land, and its evolution; the latter depends, at least partially, on climatic periodicity, both past and present, in so far as changes of climate alter the importance of different agents of erosion. The severity of erosion depends on the natural stability of the landscape, which is a legacy of its past.

This paper discusses soil erosion in relation to landform in the Dundas area of Western Victoria, Australia. In this region a polycyclic landscape has been affected by severe water erosion with associated landslides. Furthermore, changes brought about by settlement, begun only 120 years ago, are still apparent and their effect on erosion can be determined. Very little detailed mapping had been done in the area. However, outline maps, on a scale of 1 : 23,760, derived from the 1946 photo-mosaic coverage, were available but height measurements taken from aneroid readings only covered the SE. part of the area. This paper is based on data collected in the field during 1955 and 1956.

The Dundas area covers approximately 2,000 sq. m. in Western Victoria and lies 200 m. W. of Melbourne and 300 m. S.E. of Adelaide. It is a region of deeply dissected plateaux with a few residual knolls and ranges rising above the plateau levels. Although structurally it forms the W. extension of the Great Dividing Range, the N.-S. ranges of the Grampian mountains separate it from the typical rolling hill country of the Dividing Range itself. The plateaux are distinct from the relatively level emergent marine plains which surround them to the N., W. and SW., and from the rolling basalt plains of the Western District of Victoria, which themselves largely overlie marine deposits (Fig. 1).

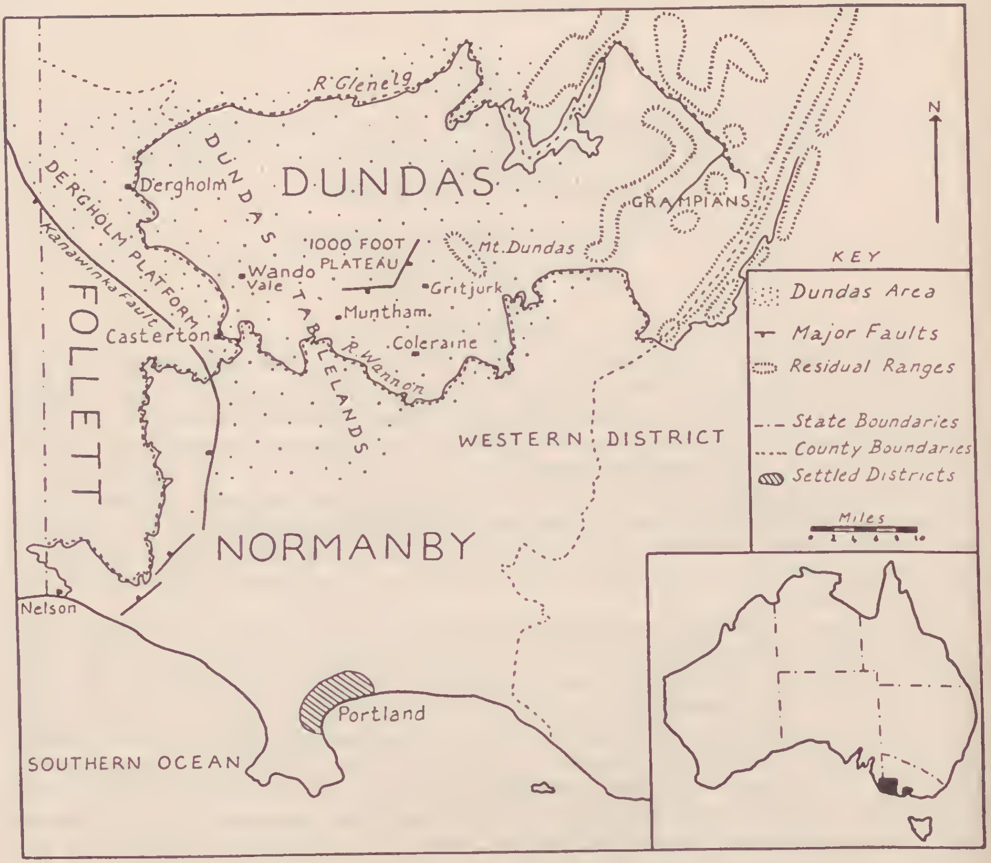

FIG. 1.—The Dundas area of Western Victoria.

Three platforms make up the Dundas area: the 1,000 Foot plateau, the Dundas Tablelands 750 to 550 ft., and the Dergholm Platform 550 to 300 ft. On the E. margin of the area the Grampians sandstone ranges and their outlier, the Dundas range, (Mt. Dundas 1,535 ft.) rise abruptly to about 2,000 ft. In the N. occasional granitic knolls reach 800 ft. The 1,000 Foot plateau is the highest surface. It is separated from the Dundas Tablelands, on its S. and E. margins, by a well-marked fault, but northwards it slopes back to merge with the lower surface. The Dundas Tablelands surround the 1,000 Foot plateau and are the most extensive of the three platforms. From their maximum elevation at the foot of the Dundas range, the Dundas Tablelands slope N. and S. towards the emergent marine plains. Westwards their trend is continued by the structurally distinct Dergholm Platform. It too slopes towards the marine plains from which it is separated by the Kanawinka Fault (Fig. 1).

All three platforms have been deeply dissected by a closely integrated drainage network (Fig. 2). The master stream, the Glenelg R., rises in the Grampians and flows N., then W. and turns S. at Dergholm, meandering across the periphery of the Dundas area to reach the Southern Ocean at Nelson (Fig. 1). Its most important tributary, the Wannon R., holds a similar course across the S. part of the area, modified in part by the Tertiary basalt flows (Fenner 1918, p. 110). A closely integrated radial stream pattern has developed tributary to the Glenelg and Wannon R. (Fig. 2). This pattern appears to have been initiated on a NW.-SE. axis which dipped NW. and which was formed before the break-up of the plateau surface. Deep dissection has taken place and down-cutting is active. The relatively short tributary streams are actively corrading their beds. Even the major rivers have steep grades in their upper courses, although they flow across flood plains above their confluence at Casterton, 200 ft. O.D.

Soil erosion has affected the channels and slopes of most of these deep valleys. Almost all the watercourses have been gullied and have cut into the old valley floors. Gullies of varying severity affect both natural and artificial drainage channels and may dissect steep slopes along lines of periodical storm flow. These gullies extend by rapid headwards erosion. Sheet erosion, however, is restricted and not serious. Landslides are the most serious feature of this erosion. Landslides, on every scale, scar and undercut many of the steeper slopes, apparently unrelated to other forms of erosion. The causes of this severe erosion must be sought in the past history of the area.

The Structure of the Land

The geological structure of the Dundas area is complicated. The area lies within the fault belt of Victoria (Boutakoff 1952, pp. 25-61). Bounded in part by faults, it has itself been faulted and differentially uplifted. The Lower Palaeozoic basement of Victoria, a complex of schists, tuffs and granitic rocks, outcrops over most of the N. part of the Dundas area. Permo-Carboniferous tillites and fluvio-glacial beds, chiefly incoherent clays and sands, have been preserved in hollows in this basement (Marker 1957 unpublished). Mesozoic lake sediments, consisting of mudstone and some felspathic sandstone, outcrop S. of a line from Dergholm to Coleraine and N. of the basalt flows (Fig. 2). Tertiary volcanic activity is represented by a series of trachyte outcrops associated with the 1,000 Foot fault. Later localized basalt flows preceded by extrusion of the main Western District basalt sheets (Marker 1957 unpublished). Thus in the Dundas area, fairly resistant Lower Palaeozoic basement rocks and Tertiary volcanics outcrop against relatively easily eroded Permian glacial and Mesozoic lake sediments. All these rocks have been bevelled by a Mesozoic-Tertiary planation surface.

This surface has been preserved by a laterite capping of probably Mio-Pliocene age (Hills 1955, p. 33). This is a fossil soil which formed on a relatively level surface, probably near base-level, under conditions of a high and fluctuating water-table (Hallsworth and Costin 1953, pp. 32-33). Extreme breakdown of rock took place during a very long period of stability. 100 ft. of soil and weathered rock are not uncommon on some granites. Alternate reducing and oxidizing conditions formed a soil with deep well-developed horizons. Underlying the topsoil which has since been wholly modified by later processes of soil formation or stripped by soil creep, an illuvial horizon of concretions formed as gravel, nodular, or massive ironstone, containing some manganese. Beneath this hard layer, which forms the present plateau capping, is a mottled red and yellow clay which passes down into bleached kaolin clay. Slight differences in texture occur in laterites developed from parent materials with different mineral compositions, but in general the laterite capping is uniform throughout the area. This fossil soil has preserved the old erosion surface. It forms a hard but permeable capping, but the clays themselves are liable to erosion, as they become fluid when saturated. Thus the presence of this laterite capping, super-

FIG. 2.—The laterite tableland cappings in relation to the geology of the Dundas area.

imposed on very varied geological strata, has increased the hazard of erosion. The uplift of such an unstable area would necessarily be followed by extensive erosion.

The Evolution of the Land

The dissection of the Dundas area has been accomplished chiefly by fluvial downcutting. This has not been a steady process. The rejuvenation of fluvial corrasion was initiated by the gradual breakup of the old surface during the Pliocene (Boutakoff 1952, p. 21). Uplift began with movement along the Kanawinka fault and 1,000 Foot fault and took place over a period of time. The intensity of the forces of erosion at work was directly related to this uplift and to the later gradual withdrawal of the sea from the foot of the Kanawinka scarp to the present coast (Sprigg 1952, p. 75). Although this area was itself unglaciated, it was affected by Pleistocene eustatic changes of sea level. The well-preserved series of relict back-shore dunes in SW. Victoria and the SE. of South Australia mark stages in the fluctuating retreat of the Pleistocene seas from a height of 300 ft. near the Kanawinka fault to 40 ft. below present sea level at the coast (Sprigg 1952, pp. 46-55). The outlet of the Glenelg R., master stream of the area, was deflected SE. to its present mouth at Nelson, where, during the last low sea level, it cut a gorge 90 ft. below present sea level (Sprigg 1952, p. 75). Flood plains associated with the post-glacial rise of sea level, have since formed upstream. Such changes in base-level, continuing into the Recent period, greatly affected the erosion of the Dundas area. Their fluctuations would tend to maintain and accentuate the inherent instability of the area by the formation of a landscape which had had no time to reach equilibrium with the forces of erosion at work on its surface.

Plio-Pleistocene and Recent climatic changes, by altering the balance between the agents of erosion, must themselves have added to this instability. With the onset of the Pleistocene glacial epoch, cool temperate conditions replaced the warm humid climate which had persisted since the formation of the laterite. Pleistocene climatic fluctuations were associated with the advance and retreat of the ice. Furthermore, during the post-glacial period one or two arid periods have alternated with a more humid climate similar to the present (Gill 1954, Whitehouse 1940). These arid periods have left their trace in the sheets of blown sand which cover the South Australian marine plains and the W. edge of the Dundas area (Fig. 2). Climatic changes over a long period of time would tend to increase the lack of adjustment between the forces of erosion and the landscape.

The present climate also accentuates this liability to erosion. Although the rainfall is relatively high, ranging from over 40 in. *p. annum* in the Grampians and 32 in. on the 1,000 Foot plateau, to 23 in. in the Coleraine valley rain shadow, it has ranged as much as 50% above or below the mean (Fig. 5). Temperatures are high enough to ensure that evaporation exceeds precipitation during the summer. Most of the area thus has a dry season of 2½ to 4 months, usually extending from early January to mid-March or April. The first rains of autumn are invariably associated with thunderstorms and fall on ground baked hard by summer heat and, after a bad season, probably devoid of protective vegetation. The climate is characterized by both seasonal and cyclic periodicity which accentuates any tendency for erosion to develop.

The Dundas area contains a legacy of inherent instability, a combination of structure and a fluctuating rejuvenation, hampered by climatic periodicity. Even in such an unstable area, equilibrium would be reached in time, but changes in the Dundas area have been too recent for this balance to be permanent.

Soil erosion, caused by the acceleration of the normal processes of erosion, now scars the slopes of the Dundas area. Any discussion of these processes must rely on recent examples which, incidentally, may be classified as soil erosion if they occur on agriculturally productive land. Since, however, similar phenomena may occur on uncleared land, less accessible to study, there appears to be no basis to justify discussing the processes of normal erosion and accelerated erosion separately.

Fluvial down-cutting is active throughout the area. Gorges and deep V-shaped valleys are usual. Gentle valley slopes are found only in the headwaters where rejuvenation is incomplete. Wide valleys with flood plains are confined to areas of weaker Mesozoic rocks, where lateral corrasion has been better able to keep pace with down-cutting. Situated in the SW. of the area, nearer base-level, these beds were first affected by renewed erosion. Erosion here has been strong enough to destroy most of the laterite residuals.

Convex slopes below the laterite crest are typical of the area, although even they are subject to channel erosion which takes the form of gullies with steeply concave profiles. The more usual concave slopes of water flow are only apparent where erosion has been greatest, particularly in the SW. Deep weathering before rejuvenation and the weak nature of much of the strata, especially the Mesozoic and Permian beds, have favoured the development of slopes by creep. The convex valley slopes are thus the product of sub-aerial weathering causing creep, which reaches maximum efficiency where soils are deep and easily moved by water lubrication. But soil creep is relatively ineffective as a valley-widening agent. Under 'normal' erosion, valleys are widened by the gradual reduction of interfluves and the lateral corrasion of closely integrated streams. In this area the slopes have been preserved by a hard capping. Down-cutting has been too rapid for tributaries to maintain their base-level and at the same time to widen their valleys. Normal valley widening has occurred only where resistance to erosion has been least. Elsewhere, valley widening has been effected by mass soil movement or landslides.

Landslides are closely associated with spring sapping below the laterite crest. They develop on clays which expand and become fluid when wet. There are two main types of landslide, depending on the water-absorbing properties of the soils. First, landslides on a concave slip plane, and secondly, mudflows with long semi-liquid tongues. Often the largest phenomena are a combination of both types (Fig. 3). Landslides, as a normal process of valley widening, may start near the top or in the middle of steep slopes. Seepage springs develop between the ironstone and clay horizons of the laterite, which lubricate the bedrock planes and, by sapping, open a wide crack at the head of the slope, which allows further percolation and lubrication. Movement begins immediately below the ironstone layer and undercuts it. Such landslides move on a concave slip plane while the clays remain solid. Often, however, movement on a concave slip plane only precedes the outpouring of the semi-liquid clay (Fig. 3).

The movements which start halfway down the slope are also due to spring sapping and water lubrication, but they are not necessarily confined to slopes with a laterite capping. They are associated with springs developed along geological junctions. These are mudflow types, most frequent on glacial and lacustrine clays which expand when wet (Thorp 1957, pp. 16-7). When the pressure of the semi-liquid clay becomes too great, it erupts from the hillside along lines of weakness, often rabbit burrows, and flows down on the surface (Downes 1949, p. 283). Slumping takes place from above.

The landslides are caused by a combination of mobile bedrock, the development of springs, and the maintenance of steep slopes. Although these movements are im-

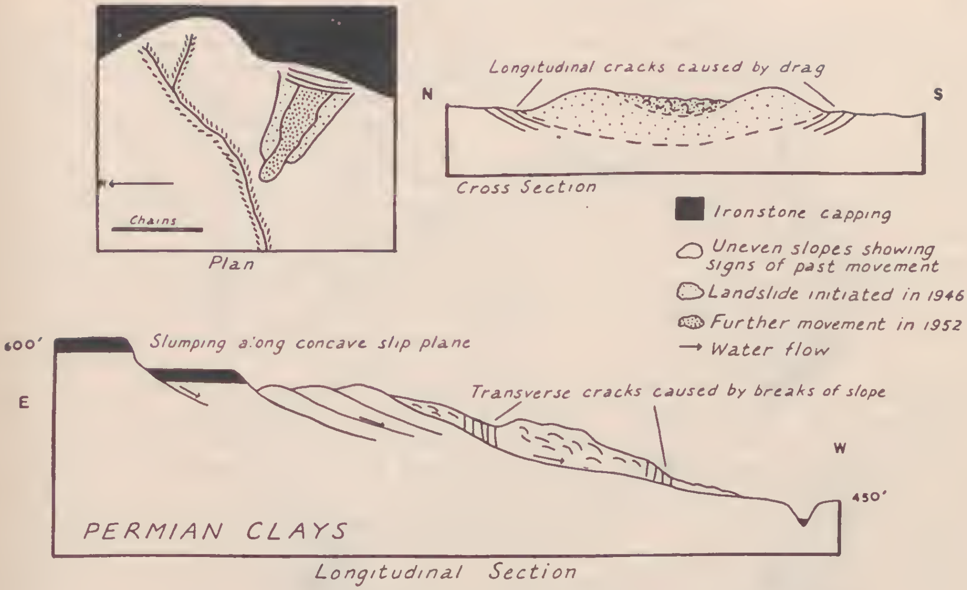

FIG. 3.—A compound landslide in glacial beds N. of Coleraine.

portant in reducing the extent of the capped interfluves, they rarely affect the whole slope. Landslides on such a large scale occur only along constricted valleys of major drainage lines. Although they may show signs of spring sapping and mudflow, they are initiated by fluvial undercutting which renders the whole slope unstable. Thus they are confined to the river cliffs of actively corrading rivers. Scars of very old landslides, half-hidden by vegetation, as well as more recent phenomena, are frequent in the valleys of the more important streams (Fig. 4). These earth movements, acting in conjunction with soil creep, appear to be the natural valley-widening process in an area of seasonal rain in a geologically weak area rendered unstable by rapid rejuvenation. Thus the normal processes of erosion in the Dundas area are fluvial corrasion, landslides and soil creep. It is likely that under natural conditions these erosion features became evident only after exceptional climatic variations.

The Settlement of the Land

The first settlers seem to have found a well-vegetated landscape with no scars of erosion. Apparently this inherently unstable area had found a precarious balance. Within a few years this was once more upset. Instability was renewed as land-use changed, and accelerated erosion became an economic problem.

In 1837 the Henty brothers reached Muntham from Portland. Settlement was rapid and by 1840 there were about 27 settlers in counties Dundas, Follett, and Normanby, outside the Settled District of Portland Bay. By 1850 there were about 127 holdings with 758,000 sheep and 66,700 cattle (Billis and Kenyon 1932). Settlement gradually became closer and stock numbers appear to have reached a peak in 1890 and then declined, reaching a second and lower maximum during the Second World War. Overstocking brought about the gradual decline in the number of cattle and sheep in the area and was accentuated by drought at the end of the

Fig. 4.—Accelerated erosion related to geological structure near Coleraine.

nineteenth century. Stock numbers alone, however, only represent a degree of overstocking. The combined effect of a rapidly increasing rabbit population, for which only estimates can be made, and a high stock density, was sufficient to alter the composition of the vegetation. Severe droughts at the end of the nineteenth century, in turn, denuded the natural pastures.

The need for self-sufficiency in the early days of settlement meant that large acreages were cleared for cultivation by European methods unsuited to Australian conditions. Much of the early erosion was caused by ploughing up and down slopes on the deeper, more fertile soils. However, cultivation ceased as soon as railway communications made cheap supplies available. Nevertheless, the change in land-use, clearing, cultivation, and heavy stocking had initiated accelerated erosion. In the past 120 years this has resulted in the lowering of the drainage lines 10 to 20 ft. below their old levels. Active rejuvenation has been initiated by the settlement of an unstable area.

Before settlement in 1837, the natural vegetation of most of the Dundas area was savanna-type open grassland, adapted to grazing by a relatively low density of native animals. The grass cover consisted of *Danthonia, Themeda* and *Stipa* species. In 1840, 37 different varieties of grass were counted on a property at Wando Vale, but after a few years the pasture composition changed (Robertson 1853). Species palatable to the closer grazing ruminant animal were eaten out. Others sensitive to trampling and burning disappeared, and the pasture became dominated by *Danthonia* species which have proved resistant to heavy grazing, close cropping, and frequent burning, whether intentional or accidental. Other perennial species were replaced by tufted annuals, or by weeds and plants unpalatable to stock. Much of this vegetation died by the end of the summer dry period, and the ground was laid bare to sheet and gully erosion during the sudden heavy storms of late summer.

The timber on the plateaux probably formed a scattered cover. On the Dundas Tablelands the most important species are Red Gum (*Eucalyptus camaldulensis* syn. *rostrata*), Manna Gum (*E. viminalis*) and Swamp Gum (*E. ovata.*). On the wetter 1,000 Foot plateau Red Gum is replaced by Snow Gum (*E. coriaceae*). With Manna Gum and Swamp Gum it formed a fairly dense woodland. The valley slopes seem to have been protected by a dense thicket of Blackwood (*E. melanoxylon*), wattles, (*Acacia armata* and *mollissima*), and Sheoak (*Casuarina stricta*). When the first settlers arrived on the Wannon a track had to be cut for the oxen. Now the same slopes are bare. On the W. sandy soils Stringybark scrub (*E. Baxteri*) and heath (*Epacris* spp.) remain the natural vegetation.

This tree cover has been severely limited by clearing and burning. During the rush of settlement, pastures were improved by the natural regeneration of native grasses after the tree cover had been thinned. Such clearing was achieved by wholesale ring-barking, a practice whereby a girdle of bark is removed from the base of a standing tree and the tree left to die *in situ*. Today, about 70% of all standing timber is dead. It has been ring-barked. Living trees are now confined to the higher parts of the plateaux and along stream banks. No trees at all to about 6 *per* acre is the present cover. The natural replacement of the trees has been prevented by heavy stocking and rabbit infestation. Seedlings can grow only within rabbit- and stock-proof fencing. Rapid destruction of a dense tree cover has upset the water regime. The full force of the precipitation now falls directly on soil no longer held together by a fine network of roots. The reduced vegetation cover absorbs less moisture. More water is available to find its way out through springs.

Under natural conditions most of the valleys were floored with rush and Tussock Grass (*Poa caespitosa*) which held together the alluvium and slowed the entry of run-off into the streams. These species were killed by the trampling of stock coming to drink and by the higher mineral content leached by the increased run-off.

The changes brought about by settlement were twofold. In the first place the changing land-use was followed by a reduction of the natural vegetation without its replacement by sown pastures. Secondly, the high rate of stocking and the cultivation of unsuitable soils resulted in the consolidation of the ground surface. Thus less precipitation was absorbed by the reduced vegetation and less could penetrate the soil. Surface run-off, especially from the slopes, increased. An unstable land was laid bare to the effects of erosion and a greater run-off increased the intensity of the processes of erosion. Accelerated erosion became evident not many years after settlement began.

Early records show that the number of springs increased soon after settlement began (Robertson 1853). While there may be a climatic explanation, it is probable that this increase is related to the disturbance of the normal water regime of the area. After the destruction of the vegetation cover more moisture was available. Some must have been absorbed by the soil, especially on the level tablelands. Much of this water then emerged as springs on the slopes below the laterite capping. The recent seasonal drying of these springs must be associated with the more rapid lowering of the water-table by the same springs. One effect of the changing land-use has been the accentuation of periodicity in the regime of the water supply, a feature which would itself increase the erosion hazard.

The development of springs was followed by the leaching of salts stored in the soil. These salts were deposited on the slopes below the springs and seepage sites and along the drainage channels. The natural vegetation was replaced by a few salt-tolerant species which were unable to protect the soil from erosion. The disappearance of Tussock Grass from the valley flats was due, in no small measure, to the increased salt content of the water which it could not withstand. Salting has become a serious problem wherever laterite forms part of a landscape undergoing accelerated erosion (Burvill 1947, p. 16).

In areas of seasonal rain, the seasonal downward movement of water is insufficient to remove all the cyclic salt brought by on-shore winds. Gradual accumulation of salt in the soil takes place, especially if the drainage is restricted. This accumulation can be very great. At Merredin in Western Australia, 150 m. inland, an average of 16 lb. of salt *per* acre *per* annum was collected over a period of 4 years (Burvill 1947, p. 15). The farthest part of the Dundas area is now not more than 90 m. inland. During the period of restricted drainage before the erosion surface broke up, the coast was closer and the amount of salt deposited presumably greater. Although some of this salt was leached during the Pleistocene rejuvenation, a proportion was retained in the soil. The recent man-induced rejuvenation has been followed by excessive seepage, with leaching and salt deposition on the slopes and drainage channels. The minerals have killed the vegetation and left the ground open to the effects of accelerated erosion.

Gullies of varying depth and severity now occur throughout the Dundas area. Some were initiated by early cultivation. Others were started by spates along drainage channels and stock tracks. Today, every slope is cut by gullies 15 or more ft. deep. Their severity is a measure of this recent rejuvenation initiated by increased run-off.

Soil creep only becomes an economic problem, however, where the vegetation has been stripped on the steepest slopes. Deeply weathered granites have alone proved vulnerable to soil wash. Elsewhere it can be controlled by pasture management. However, the tilted fences and telephone poles, even on moderate slopes, testify to the presence of active creep which can become a serious problem on badly managed slopes.

The acceleration of erosion has been followed by extensive landslides. These are serious as they affect many slopes in the more fertile farming areas. Landslides may occur at the top, in the middle and at the bottom of slopes. Major movements, starting immediately below the ironstone capping, although common, are localized. They occur in two areas—along the upper Glenelg valley, and S. of a line from Gritjurk to Muntham. They are confined to slopes on unstable Permian glacial beds and incoherent Mesozoic sediments (Fig. 4). Only a few large landslides have occurred outside these zones, on deeply weathered granite slopes.

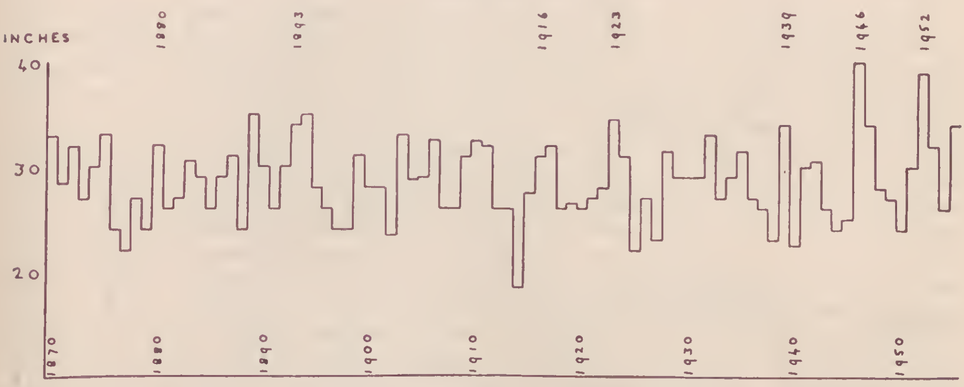

FIG. 5.—Rainfall fluctuations in the Western District of Victoria, 1870-1955.

Landslides at the bottom of slopes, caused by streams undercutting unconsolidated beds, have become frequent. Some occur in the lateritic clays where the streams have not yet cut through into bedrock. Others occur along streams cutting through weathered granite, Permian beds, or Mesozoic sediments. But such landslides are not peculiar to this district. They occur wherever accelerated erosion has led to the rapid deepening of channels by gullying.

Although major landslides are known to be due to the acceleration of the normal processes of erosion in this unstable area, they also appear to be related to the incidence of precipitation. A series of dry years when the vegetation will be considerably depleted, followed by a wet year, favours movement. Many recent landslides were initiated in 1946 when 10 in. of rain fell in March after a dry summer, and in 1952, another wet year (Fig. 3). A study of the annual rainfall totals for the Western District of Victoria suggests that 1880, 1893, 1916, 1923, 1939, 1946, and 1952 were all liable to landslides (Fig. 5). These landslides are a potential danger on the unstable clays of the Dundas area. Their initiation and maintenance is governed largely by seasonal climatic conditions.

Some deposition of coarse material has occurred on many valley flats and is gradually filling in the beds of streams, making them more liable to flood. Within living memory water holes have silted up. Yet, as the flats are not considered good farmland, the problem has scarcely been considered as a product of accelerated erosion.

Conclusion

Accelerated erosion in its most serious form is manifest throughout the Dundas area; this area has been classified as one of the worst affected in the State of Victoria. Erosion has become a feature of the landscape almost within living memory. For this reason it has been considered as a man-made problem. Accelerated erosion has been induced by a rapid increase in the run-off from springs and from the surface, caused by the destruction of the natural vegetation as a result of burning, clearing, and grazing. This has been the usual sequence in the lands colonized during the nineteenth-century expansion, yet not everywhere has it been followed by acute soil erosion, the product of accelerated erosion. Only in those areas which were inherently unstable could rapidly changing social conditions bring about such a rapid and disastrous rejuvenation of the erosion processes.

The Dundas area is a naturally unstable area with a legacy of past instability. The advent of settlement upset the precarious balance and was followed by an acceleration of erosion sufficient to initiate a new cycle of erosion. Usual methods of erosion control will be relatively ineffective here, by treating individual outbreaks, until the steepest slopes have reached a more gentle angle of rest and the tributary streams grade, within their profiles. The improvement of deteriorating soils by the use of fertilizers, and the growth of an adequate vegetation cover, using introduced sown pastures, can do much to reduce present run-off and allow a new equilibrium to be reached. This is the only possible economic policy. Either the land will deteriorate further until it becomes too costly to work, or expensive improvements must be undertaken. These improvements will themselves increase the carrying capacity of the land and thus, ultimately, repay the initial outlay again and again. Such pasture development, however, will be ineffective unless it is accompanied by careful grazing management and the control of rabbits. In the Dundas area man has interfered, albeit unwittingly, with a particularly precarious equilibrium. Only if man can reduce the consequences of his earlier policy, can there be any hope of reaching a new equilibrium.

References

Billis, R. V. and Kenyon, A. S., 1932. *Pastoral pioneers of Port Phillip.* Macmillan. Melbourne.

Boutakoff, N., 1952. The structural pattern of S.W. Victoria. *Min. Geol. J.* 4(6) : 21.

Burvill, G. H., 1947. Soil salinity in the agricultural areas of Western Australia. *J. Aust. Inst. Ag. Sc.* 13: 9.

Downes, R. G., 1949. Tunnelling erosion in N.E. Victoria, *J. C.S.I.R.O.* 19: 283.

Fenner, C., 1918. The physiography of the Glenelg river. *Proc. Roy. Soc. Vict.* 30: 99.

Gill, E. D., 1954. The Australian arid period. *Aust. J.Sc.* 17(6).

Hallsworth, E. G., and Costin, A. B., 1953. Studies in pedogenesis in New South Wales. IV. The ironstone soils. *J.Soil Sc.* 4(1) : 53.

Hills, E. S., 1955. *Introducing Victoria,* Ch. III. (ed. G. W. Leeper). Melbourne.

Marker, M. E., 1957. The physiographic evolution of the Dundas area of W. Victoria, with reference to soil erosion problems. M.Agr.Sc. Thesis (Unpublished), Library, University of Melbourne.

Sprigg, R. C., 1952. The geology of the South-east province of South Australia with special reference to Quaternary coast-line migrations and modern beach development. *Geol. Survey S.A.* Bul. 29.

Thorp, J., 1957. Report on field studies of soil in Australia. *Sc.Bull.*1. Earlham College, Indiana, U.S.A.

Whitehouse, F. W., 1940. Studies in the late geological history of Queensland. *Univ. Queensland papers. Dept. Geol.* No. 1.